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CONSIDERATIONS ON AIRCRAFT AUTORECOVERY BASED ON +Gz-INDUCED LOSS OF CONSCIOUSNESS

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The approach to aircraft autorecovery demands consideration of many aspects of fighter aircraft operations and aircrew requirements. Autorecovery may include only aircraft attitude monitoring or it may also include consideration of the aircrew. A knowledge of the kinetics of +Gz-induced loss of consciousness (G-LOC) allows early development of an inexpensive, non-encumbering, indirect method for G-LOC warning which may be followed by autorecovery if necessary. This indirect method has specific advantage for aerial combat training. Integration of an indirect monitoring system with the ground collision avoidance system currently being developed has the potential for earlier aircraft recovery. A suggested algorithm based on G-LOC physiology is given. Development of indirect monitoring systems provides valuable insight into future development of more sophisticated direct physiologic monitoring technology. It is currently not clear that the ability to reliably detect G-LOC with direct aircrew monitoring will automatically benefit aircrew during aerial combat.

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INTRODUCTION

Although it may seem simple and straightforward, there are multiple aspects which must be considered relative to development of systems for aircrew monitoring for +Gz-induced loss of consciousness (G-LOC) and subsequent aircraft autorecovery (Table 1). Aircraft autorecovery without aircrew monitoring has been demonstrated to be feasible but has certain characteristics which may be improved upon (2). Aircraft autorecovery with aircrew monitoring has not been demonstrated. Aircrew physiologic monitoring systems are likely to suffer from a number of evident operational drawbacks. These drawbacks include increased cockpit equipment, aircrew encumbrance, lack of reliability in a combat scenario, and lack of time for resultant aircraft recovery. Aircrew acceptance of suitable monitoring techniques remains a problem in itself. For these reasons physiologic monitoring of the fighter pilot during aerial combat maneuvering may not prove to be practical (or acceptable) even if it can be accomplished technically. An alternative to physiologic monitoring may involve utilization of the detailed characteristics of the +Gz-induced loss of consciousness (G-LOC) phenomenon which may be more likely to be operationally useful (and acceptable) for integration with aircraft autorecovery. Based on the human physiologic response to rapid-onset, sustained +Gz stress and the conditions that are necessary to induce G-LOC, a G-LOC warning system could be developed and undergo early implementation. The aircraft autorecovery sequence can likewise be developed based solely on G-LOC characteristics, including G-LOC warning and pilot autorecovery warning followed by initiation of aircraft autorecovery. Non-nuisance warning requirements are important such that pilot disturbance during a critical moment of weapons employment are avoided. Such a system may be of particular benefit during aerial combat training. Based on actual aerial combat acceleration profiles it is likely that such a system could be developed, at low cost, requiring relatively infrequent warning only during high risk +Gz maneuvering profiles. It is evident that aircraft autorecovery without monitoring will always be a requirement, even if reliable and acceptable aircrew monitoring techniques are developed.

Table 1. Approaches to Aircrew G-LOC Monitoring
and Aircraft Autorecovery.

1. Critical Physiologic System Compromise
   (example: cerebral blood flow monitoring)

2. G-LOC Warning (example: +Gz-exposure monitoring)

3. G-LOC Detection
   (example: electroencephalographic monitoring)

4. Aircraft Autorecovery Initiation Warning

5. Aircraft Autorecovery

6. Optimum Aircraft Recovery

7. Optimum Aircrew Recovery

A detailed analysis of the exact method(s) of operational implementation of physiologic monitoring techniques should be accomplished before resources are directed toward their development. The assumption that once a suitable physiologic monitoring technique for G-LOC detection is available, it will automatically be of direct benefit for the operational aerial combat environment, is not necessarily correct.

DESCRIBING G-LOC AND TOLERANCE TO $+G_z$

The characteristics of the human response during G-LOC were developed from detailed review of over 500 videotaped centrifuge G-LOC episodes (8). These G-LOC episodes were part of a centrifuge data repository which has been in existence for over ten years (1977-1987). The subjects experiencing G-LOC included experimental subjects, students in aerospace disciplines, and various aircrew. The +Gz-profiles inducing G-LOC included onset rates from 0.015 G/s to 6 G/s and +Gz-levels from +2.5Gz to +9.0Gz.

Specific descriptive time periods have been developed and form a kinetic description of the G-LOC phenomenon. These include the central nervous system (CNS) functional buffer period; the absolute, relative and total incapacitation periods; and the convulsion free and convulsion prone periods (6). Hydraulic and relaxed cardiovascular +Gz-level tolerances have been previously established (5).

G-LOC AND AUTORECOVERY WARNING WITHOUT DIRECT PHYSIOLOGIC MONITORING

The critical factors in designing this indirect type of G-LOC warning with a subsequent autorecovery initiation warning system for high performance fighter-type aircraft are given in Table 2 and Figure 1. G-LOC warning is dependent upon the +Gz-onset rate, the time-dependent +Gz-level tolerance limits (hydraulic and cardiovascular), the sustained +Gz-period, and the CNS functional buffer period. Autorecovery warning and initiation is further dependent on the absolute incapacitation period and the associated characteristics of the convulsion free period and convulsion prone period.

Table 2. G-LOC Warning and Autorecovery Initiation Critical Factors.

	Factor	G/time
1.	+Gz-onset Rate	$\geq$1.0G/S
2.	Hydraulic +Gz-level Tolerance	$\geq$+3.2G
3.	Sustained +Gz Period	$\geq$7.0s
4.	CNS Functional Buffer Period	7s
5.	Absolute Incapacitation Period	12s
6.	Relative Incapacitation Period	12s
7.	Convulsion Free Period	8s
8.	Convulsion Prone Period	4s

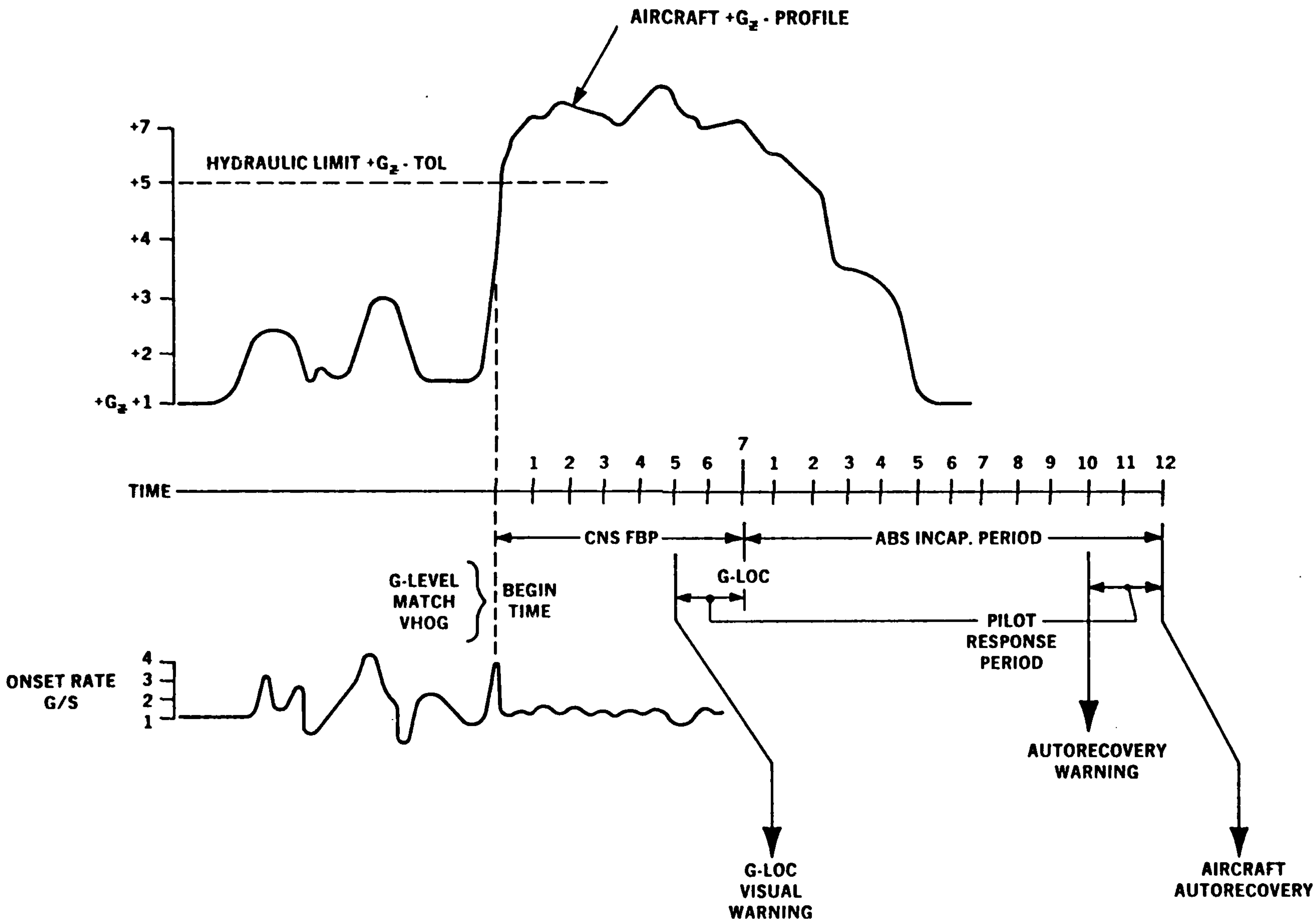

Figure 1. Diagrammatic description of G-LOC and the factors required for indirect monitoring for inflight G-LOC and aircraft autorecovery.

If an aircraft maneuver exceeds the hydraulic +Gz-level tolerance limit with very high onset +Gz (VHOG), then a G-LOC warning could be initiated after an appropriate period if the +Gz-level is sustained. It must optimally, however, be initiated prior to exceeding the CNS functional buffer period. The G-LOC warning would have to be issued in time to be recognized by the pilot, allow human and aircraft response, and time to reduce the +Gz-level to allow reperfusion of the CNS -- a tall order in such a limited time space. Physiologic requirements for maintenance of consciousness dictate that the +Gz-offset rate be rapid to a +Gz-level below +3Gz so that CNS blood flow is re-established before the CNS functional buffer period is exceeded. When considering the aircraft autorecovery system, an autorecovery initiation warning (that is, an indication that aircraft control is about to be taken from the pilot) would be initiated after a period longer than the CNS functional buffer period but a period that would allow recognition and cancellation of autorecovery (if the pilot is indeed conscious). Pilot acceptance of aircraft autorecovery should be enhanced if he will be adequately warned of impending usurpation of aircraft control in time for cancellation. To avoid unnecessary and frequent nuisance warnings and assure that autorecovery is initiated only when the pilot is unconscious, the sequence of G-LOC warning, autorecovery warning, and aircraft autorecovery could be aligned in series. A visual G-LOC warning could be initiated prior to the end of the CNS functional buffer period. An auditory autorecovery warning, initiated prior to actual aircraft autorecovery engagement, would be more demanding of pilot attention. A potential algorithm can be developed for a very rapid onset +Gz exposure based of these principles as shown in Figure 2. Assuming a CNS functional buffer period of 7s and a desire to autorecover within l2s of G-LOC, the visual warning might be initiated at 5s, giving 2s for +Gz reduction, followed by an auditory warning at 10s, giving 2s for pilot response to cancel the aircraft autorecovery engagement. The pilot response to cancel autorecovery should be simple, non-task disruptive, and easily accomplished. It must avoid adverse impact on continued aerial combat maneuvering if necessary (and if conscious). Stick flight control input may be considered as a potential candidate for pilot autorecovery cancellation prior to initiation and pilot autorecovery disengagement after initiation. The occurrence of

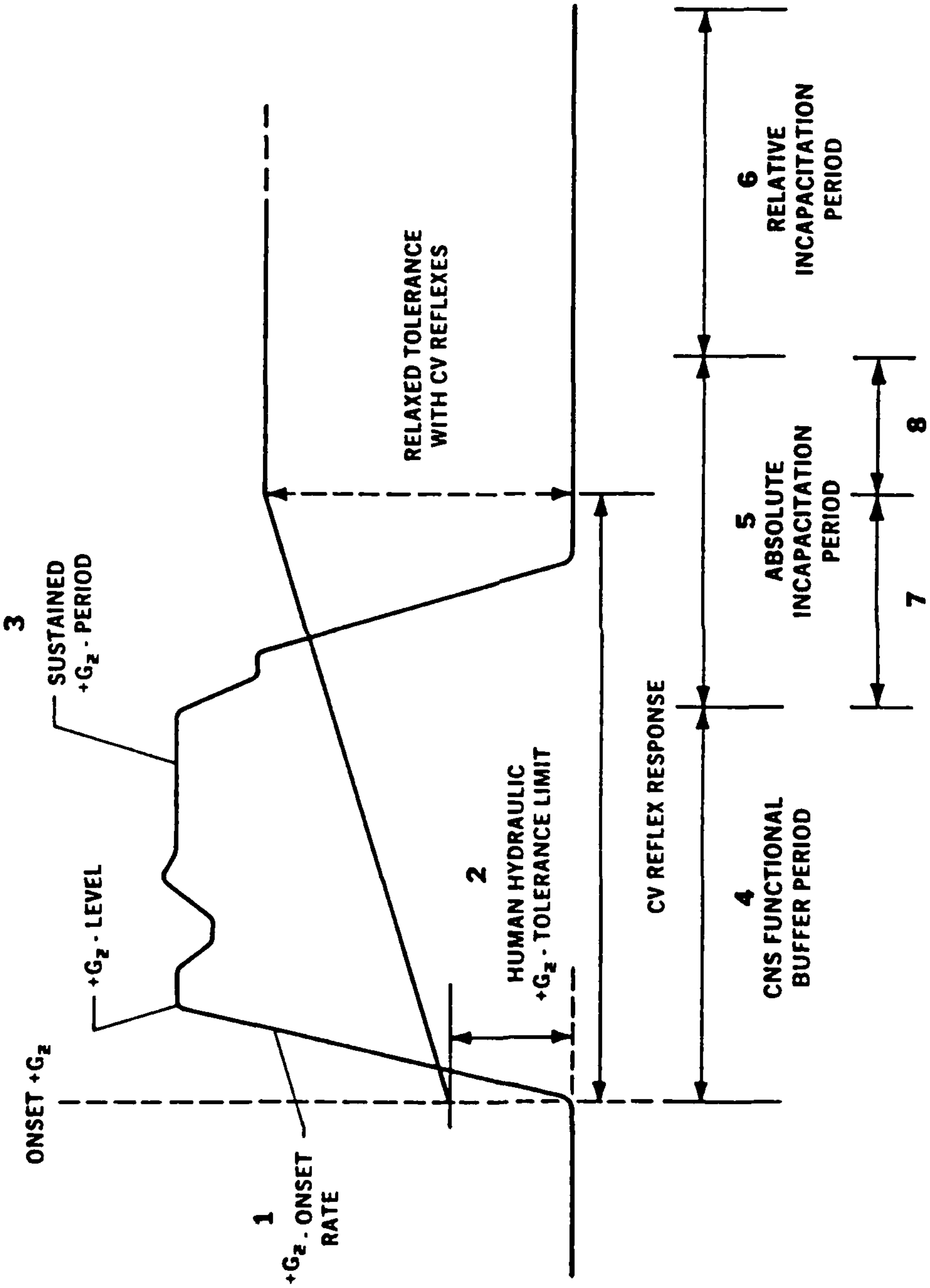

Figure 2. Algorithm for G-LOC warning sequence leading to aircraft autorecovery based on +Gz-time exposure and physiologic principles.

myoclonic convulsive flail movements of the upper extremities have the potential for occurring and providing false autorecovery cancellation (disengagement) if they occur within the critical time window and are of a nature that could be mistaken for purposeful input. Myoclonic convulsions occur during the last 4s of the typical 12s absolute incapacitation period. This 4s period has been termed the convulsion prone period. The first 8s of the absolute incapacitation period is the convulsion free period. Characteristics of the myoclonic convulsions must be considered in the ultimate design of such autorecovery systems.

Human +Gz-level tolerance must also be factored into the warning algorithm. For initiation of the warning sequence, an absolute +Gz-level may be utilized to aid in reducing nuisance warnings and simultaneously provide the widest safety margin. The G-LOC/autorecovery warning and the aircraft autorecovery sequence would be initiated when the exposure +Gz- level reaches a specific predetermined level. Since relaxed, hydraulic +Gz-level tolerance to VHOG is, on the average, around +3.2Gz, this might be considered as the set point for sequence initiation. It should be noted that this level could be individually determined by measuring aircrew relaxed hydraulic tolerance to VHOG as a specific part of centrifuge high +Gz training, when it is available. Since individual +Gz-tolerance is variable and safety of high priority, the +Gz level for sequence initiation should probably be conservative. Review of the U.S. Air Force and U.S. Navy G-LOC surveys lends support for establishing a relatively low trigger level since most in-flight G-LOC episodes occurred at moderate +Gz levels between +5Gz and +7Gz with some as low as +4Gz (3,4). The most threatening +Gz-profile must still be considered to be a sustained, VHOG to high +Gz. In the U.S. Navy survey this type of exposure represented 27% of the reported in-flight G-LOC episodes. Another 27% of the episodes occurred in a relatively relaxed state with little or no anti-G protection (no anti-G suit, improper or no performance of the anti-G straining maneuver, and unprepared for the stress). Review of the +Gz environments of current U.S. Air Force fighter aircraft has shown what the typical F-15 and F-16 times above various +Gz-levels per engagement (see Table 3)

Table 3. F-15/F-16 Engagement Time Spent Above Various +Gz-Levels.

	Mean Total Time	
+Gz - Levels	F-15	F-16
+5Gz	21.8	20.3
+6Gz	8.4	7.8
+7Gz	1.3	2.0
+8Gz	0.0	0.2

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Table 4. Frequency of Warning Intervention as a Function of Sequence Trigger Set Point.

Trigger +Gz-Level Set Point	Number of Times for Warning G-LOC Warning	Autorecovery Warning
+3.2Gz	6	2
+4.0Gz	6	1
+5.0Gz	4	0
+6.0Gz	0	0
+7.0Gz	0	0

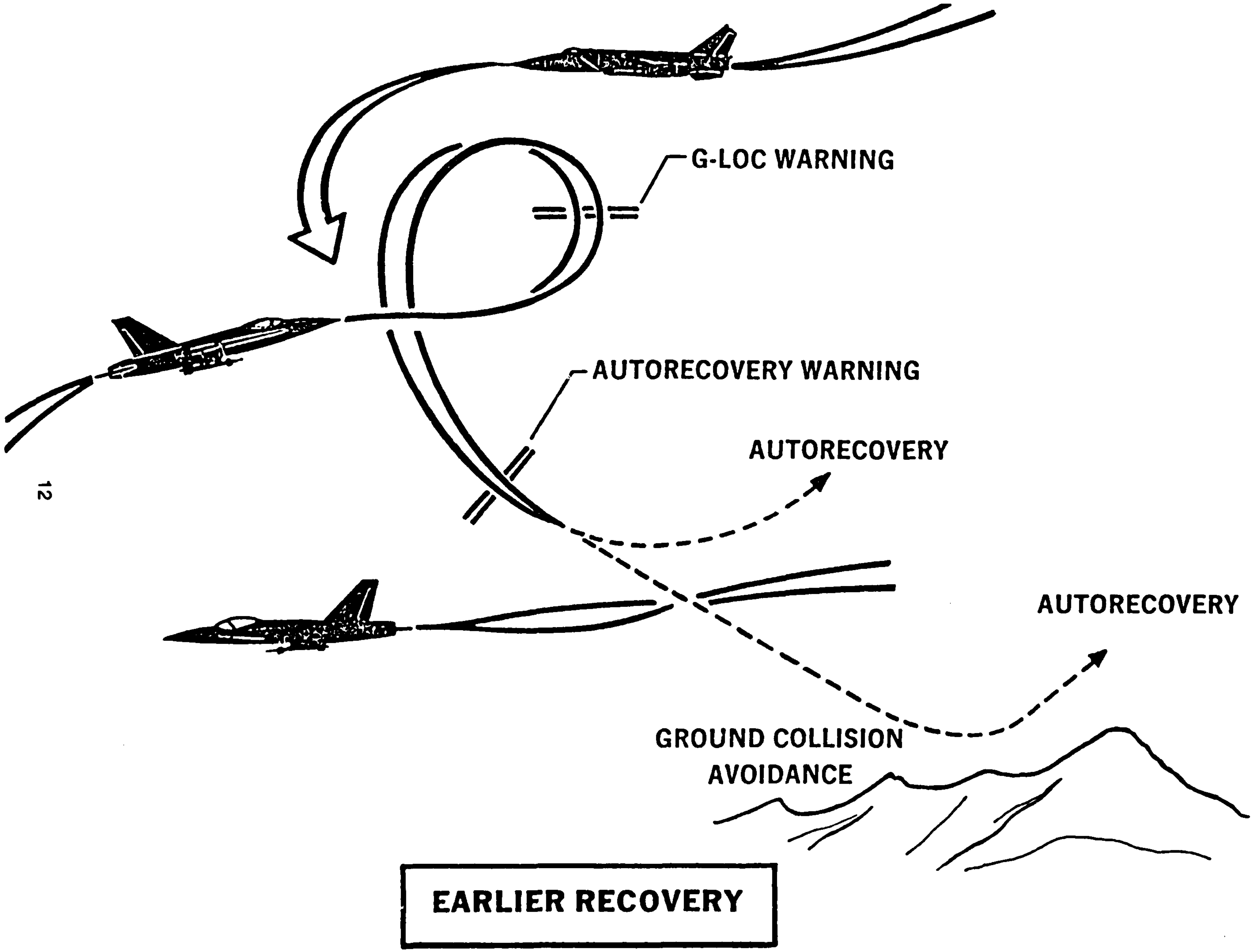

Figure 3. Combination of indirect monitoring and ground collision avoidance systems for aircraft autorecovery.

are about to be exceeded. Up to that point, the pilot could safely maneuver with confidence throughout the maximum +Gz maneuverability envelope of the aircraft. Since system cost is very low, it would be extremely cost effective. It is compatible with existing and future aircraft, and the technology development would be of benefit to future development of other direct physiologic monitoring techniques. If utilized in combat, the absence of complexity and the lack of technical skill for maintenance makes it much more combat worthy as compared to sophisticated and encumbering physiologic G-LOC monitoring technologies.

DIRECT PHYSIOLOGIC MONITORING TECHNIQUES

Let us now examine some aspects of physiologic monitoring with regard to the improvement which could be expected over the system just described which is based solely on human acceleration physiologic response and the aircraft +Gz-time history. Physiologic monitoring system theory is currently based on *either determination of unconsciousness* (G-LOC detection) or determination of a physiologic change which prestages G-LOC. We will describe these two approached as G-LOC monitoring and physiologic monitoring, respectively.

Physiologic monitoring of a critical function, such as cerebral blood flow (CBF), might be considered the optimum technique since it determines the exact moment when physiologic compromise begins. Even so, this still depends on a knowledge of the CNS functional buffer period to prevent unnecessary nuisance warning. The benefit this system has is an exact knowledge of the time at which consciousness begins to depend on the CNS functional buffer period. This is an improvement over an estimation based upon the +Gz-level exposure, but it must be weighed against the additional pilot encumbrance, cockpit modification, and the level of difficulty in obtaining a reliable physiologic signal. Time must be allotted for aircrew warning of aircraft autorecovery initiation. Proven physiologic monitoring techniques

are available but as yet have not been developed for reliable, non-invasive use in operational environments.

The G-LOC monitoring approach, on the other hand, does allow an immediate initiation of autorecovery, but is too late for any warning to prevent G-LOC. A finite period of time for aircraft autorecovery warning of the pilot would still be a requirement. Even if a reliable technique, free of added aircrew bulk and cockpit complexity, can be developed, aircrew may still request aircraft autorecovery warning prior to aircraft autorecovery initiation. No proven G-LOC monitoring techniques have been operationally demonstrated. They also require monitoring equipment in the cockpit and/or on the aircrewman, whereas utilizing a system strictly based on the +Gz time consideration does not. At least as an initial step toward future direct physiologic monitoring of aircrew for aircraft autorecovery, the simpler approach may be developed earlier. The complexity of the monitoring/detection task may require a multisystem physiologic monitoring approach to assure reliability in operational flight environments. Multiple system monitoring approaches still have the same disadvantages as previously described, even though they may be able to more exactly determine pilot incapacitation.

AIRCRAFT AUTORECOVERY WITHOUT PHYSIOLOGIC CONSIDERATION

The functional capability of an aircraft autorecovery system, devoid of any direct physiologic sensors or indirect physiologic considerations, has been demonstrated with the Advanced Fighter Technology (AFTI) F-16 (2). Emphasis was placed on developing a reliable system which was simple and had wide applicability. It was also important for the system to be capable of being fully integrated with existing weapon systems. Since direct physiologic monitoring systems have remained complicated and based on unproven technology they were not considered for short term utility. An autorecovery system based on the above mentioned indirect physiologic considerations is consistent with these original goals of the cur-

rent AFTI F-16 autorecovery technology. This indirect monitoring system based on physiologic principles could make a significant enhancement of the currently available system and be completely compatible with all future systems. It could result in earlier initiation of autorecovery in peacetime training or a combat scenario. In addition, it provides a G-LOC warning not currently available, and therefore may serve to prevent certain G-LOC episodes with associated increased risk. Software changes are most likely the only required changes (additions) to the existing system. The requirement for complex and potentially combat unreliable physiologic monitoring instrumentation is completely eliminated. Although the current ground collision avoidance system could, in the short-term, enhance safety, the desire to eliminate radiating sensors from aircraft still remains a desirable goal.

SUMMARY

The overall analysis of G-LOC characteristics results in the autorecovery algorithm shown in Figure 3. As such, it is designed to effectively counter VHOG induced Type II G-LOC (7) based on the average human response. It assumes a most conservative +Gz hydraulic tolerance limit for sequence initiation, that of a relaxed individual not performing an anti-G straining maneuver or wearing an anti-G suit. This is probably not unrealistic based on the relatively moderate +Gz-levels responsible for the most frequent episodes of G-LOC, and the frequent inadvertent failure of anti-G protection (anti-G suit/anti-G straining maneuver) (3,4). The algorithm is based solely on an understanding of G-LOC physiologic principles without requiring encumbering physiologic monitoring or complex cockpit modification. Validation of this approach, and the exact sequence trigger set point, could be accomplished utilizing currently available inflight aerial combat profiles. Research efforts which pursue more sophisticated monitoring techniques must be evaluated in terms of operational employment and the additional gains which may result. Even if specific monitoring/detection techniques evolve, consideration must be given to the methods of their integration into the detailed operational autorecovery sequence. In the short-term, integration of the current

non-physiologic AFTI F-16 autorecovery technology could be combined with the described indirect physiologic principles to enhance aerial combat safety. Long term goals must include continued evaluation of sophisticated physiologic monitoring of aircrew.

References

1 Gillingham KK, Plentzas S, Lewis NL. G environments of F-4, F-5, F-15, and F-16 aircraft during F-15 tactics development and evaluation. USAFSAM-TR-85-51; USAF School of Aerospace Medicine; Brooks AFB, Texas 1985.

2 Howard JD, Johnston AM. AFTI/F-16 gravity-induced loss of consciousness and spatial disorientation autorecovery system. Proceedings of the IEEE National Aerospace and Electronics Conference, Dayton Ohio, 1986: 752-759.

3 Johanson DC, Terry DM. An in-depth look at the incidence of in-flight loss of consciousness with the U.S. Naval service: A final report. Naval Weapons Center; China Lake, CA. NWC TP6737, July 1986.

4 Pluta JC. LOC survey. Flying Safety 1984; 25-28.

5 Whinnery JE. +Gz tolerance correlation with clinical parameters. Aviat Space Environ. Med. 1979. 50: 736-641.

6 Whinnery JE. Observations on the theory of acceleration (+Gz) induced loss of consciousness. Aviat Space Environ. Med. (submitted).

7 Whinnery JE, Burton RR, Boll PA, Eddy DR. Characterization of the resulting incapacitation following unexpected +Gz induced loss of consciousness. Aviat Space Environ. Med. 1987; 58:631-636.

8 Whinnery JE, Whinnery AM. Acceleration induced loss of consciousness, (manuscript in preparation)

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